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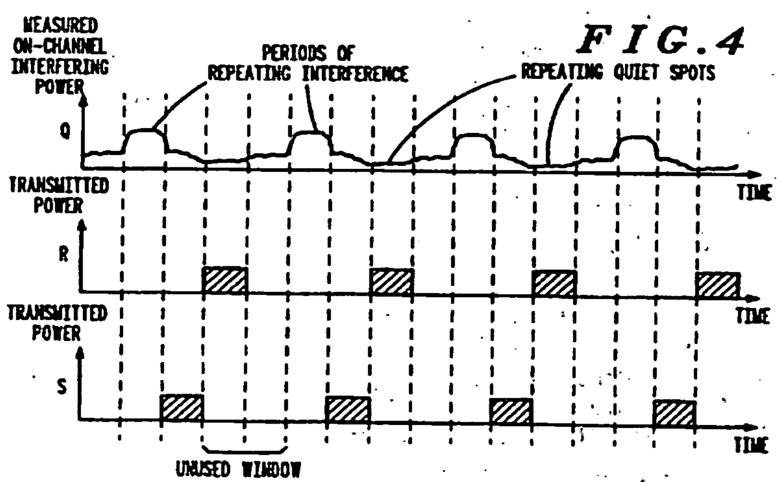
(54) **Communications device with adaptive burst transmission time to avoid periodic interference**

(57) A communications system having units communicating in periodic bursts over a time divided channel is described. A periodic time window R is identified, repeating between peaks of activity Q on the channel, having a duration at least equal to the duration of a transmission burst. That time window is selected as a repeating time slot for transmission. In another aspect, bursts of transmission are received from a unit including traffic (for outputting) and signalling is transmitted to the unit in bursts interspersed between received bursts on the same channel, where the unit which is receiving traffic and transmitting signalling times the bursts transmitted according to the bursts received. In another aspect, a pre-emption requirement is relayed from a receiving unit which may be in range of a pre-empting unit to a transmitting unit which may not be in range of the pre-empting unit.

FIG.4



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

FIG.1

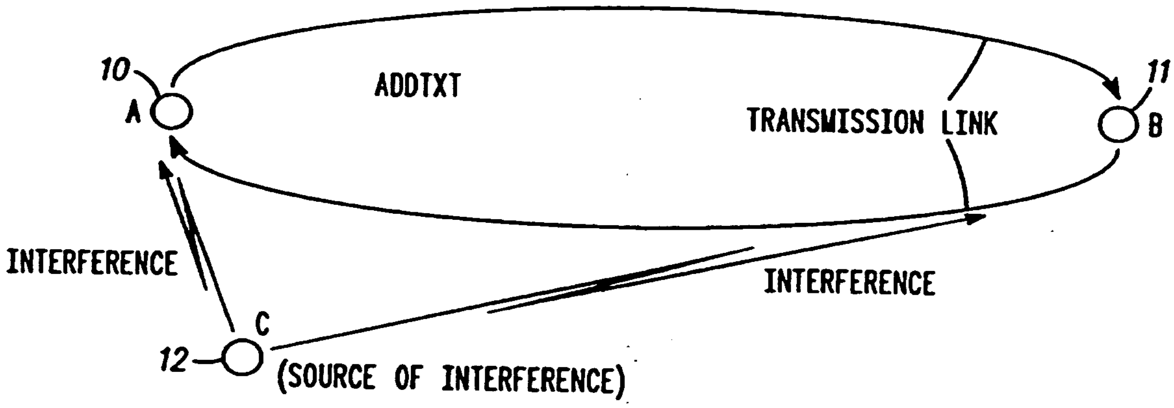


FIG.2

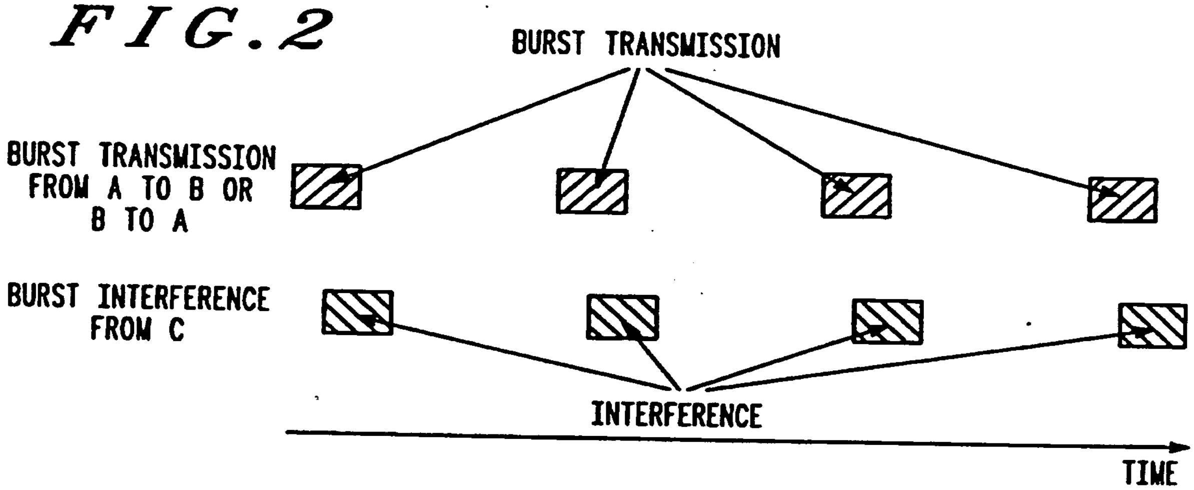
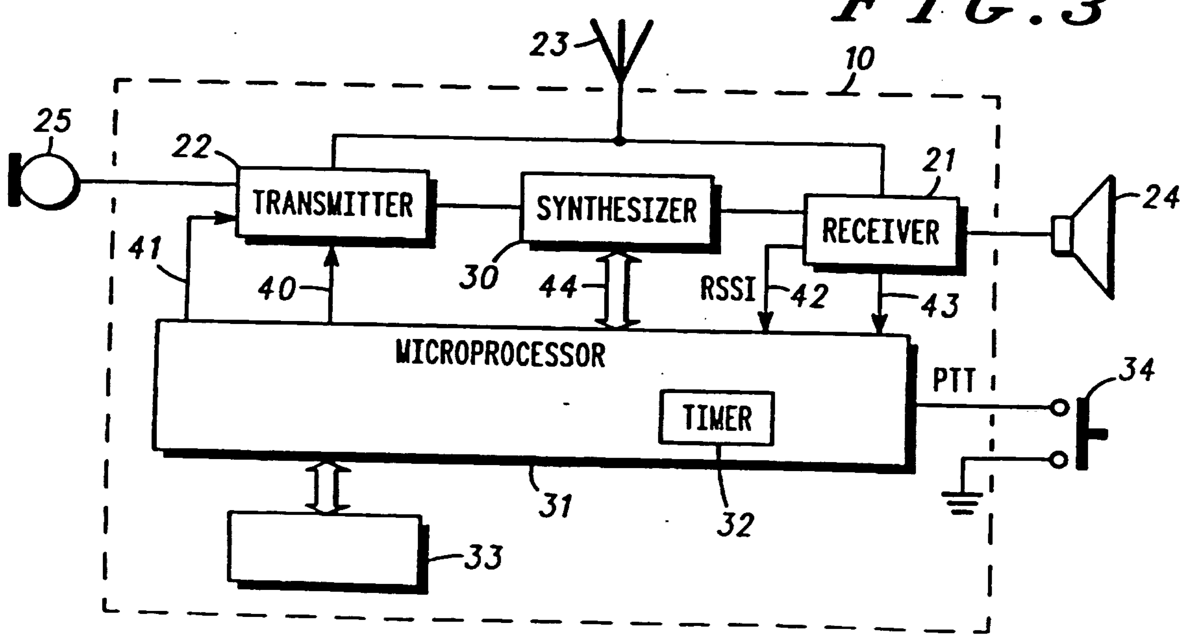


FIG.3



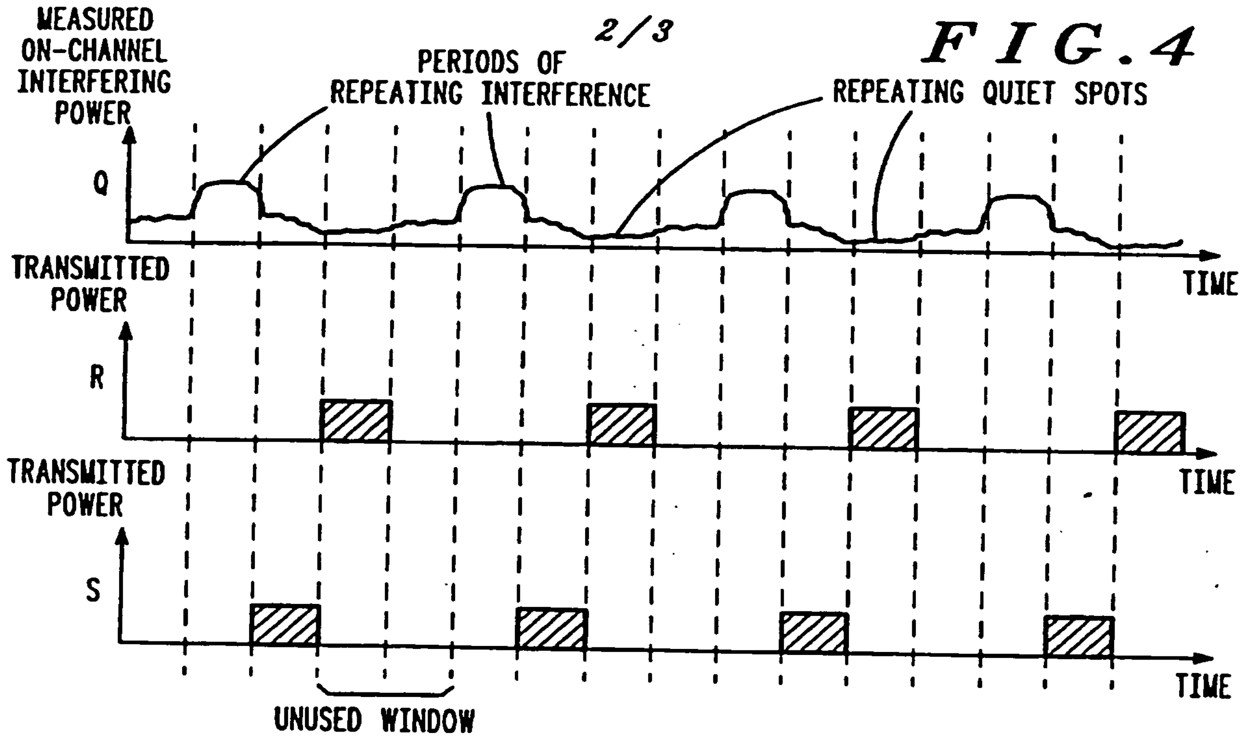


FIG. 4

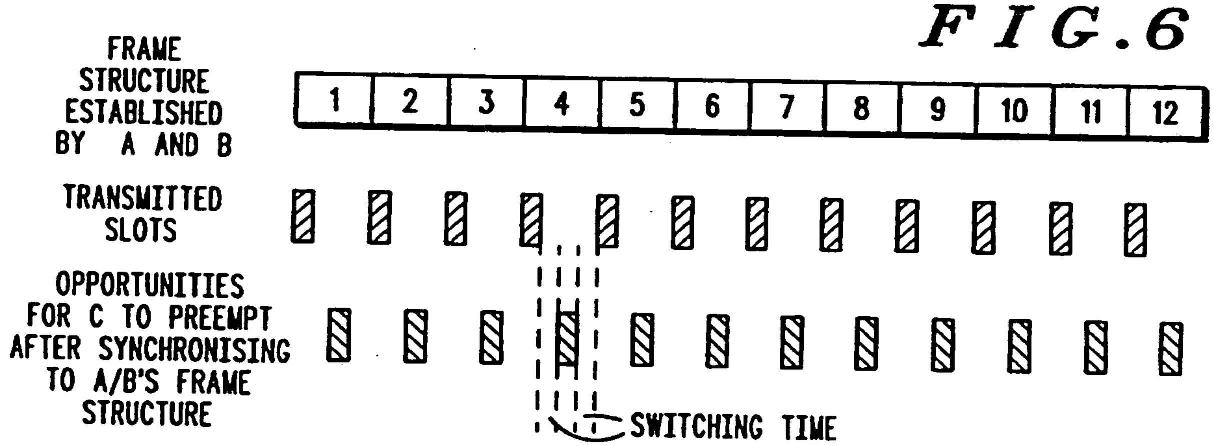


FIG. 6

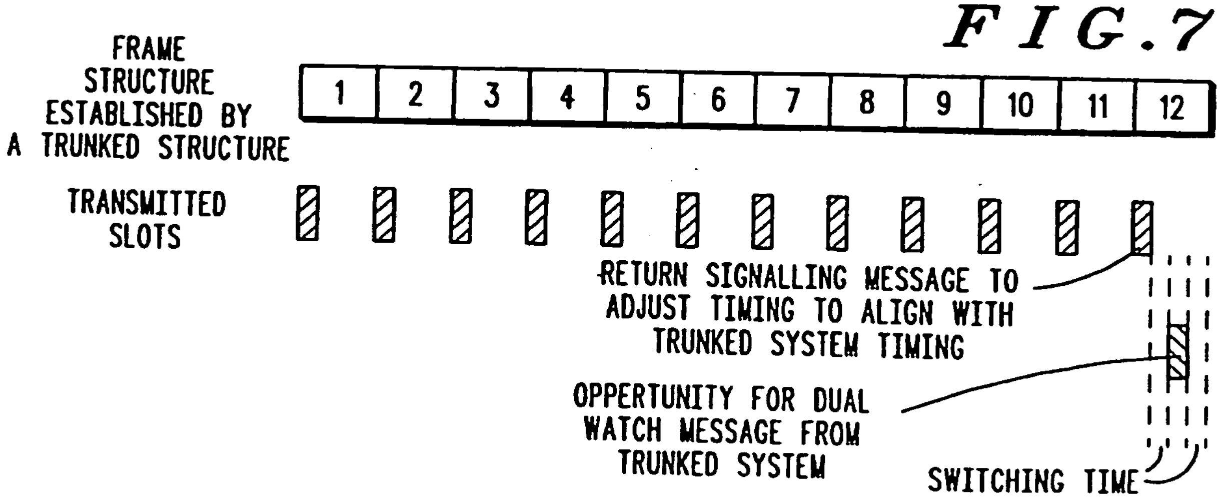


FIG. 7

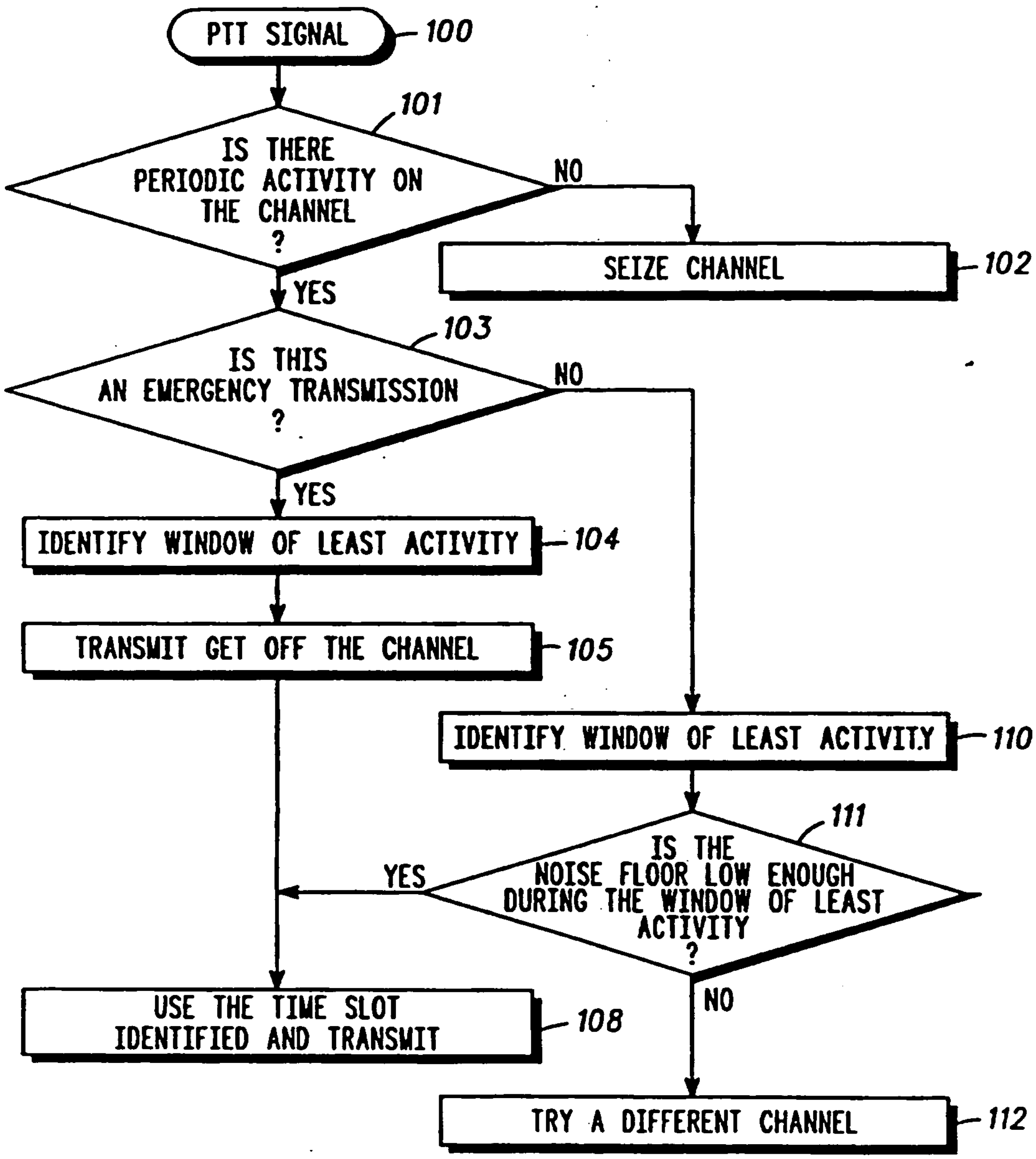

PTT SIGNAL
100
IS THERE PERIODIC ACTIVITY ON THE CHANNEL ?
101
NO
SEIZE CHANNEL
102
YES
IS THIS AN EMERGENCY TRANSMISSION ?
103
NO
YES
IDENTIFY WINDOW OF LEAST ACTIVITY
104
TRANSMIT GET OFF THE CHANNEL
105
IDENTIFY WINDOW OF LEAST ACTIVITY
110
IS THE NOISE FLOOR LOW ENOUGH DURING THE WINDOW OF LEAST ACTIVITY ?
111
YES
NO
USE THE TIME SLOT IDENTIFIED AND TRANSMIT
108
TRY A DIFFERENT CHANNEL
112

FIG.5

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Communications Device and Method with Adaptive Burst Transmission Time and Other Features

Field of the Invention

This invention relates to a communications device and method having, in one aspect, adaptive burst transmission time and, in other aspects, return burst signalling and pre-emption features.

Background to the Invention.

A number of communications systems exist where information is transmitted/received as a series of bursts at regular intervals of time (e.g. a time division multiple access - TDMA - system) across a transmission link. Such systems include GSM cellular radio, CT2 and DECT standards for cordless telephone and the TETRA standard for trunked mobile radio.

In such systems, rigorous specifications are set out for avoiding interference between a signal or signals on one carrier frequency and a signal or signals on an adjacent carrier frequency. This is frequently referred to as adjacent-channel interference. An important aspect of reducing adjacent-channel interference is having highly accurate frequency of transmissions, using an accurate signal from a base station as a reference frequency. Typically a base station may have a frequency tolerance of 0.2ppm while a mobile may have a frequency tolerance of 2ppm.

In cellular-type radio and trunked mobile radio, there is usually provision for more than one user on a single frequency carrier, in TDMA manner. Interference between signals on the same carrier is frequently referred to as co-channel interference. A principal feature for avoiding co-channel interference is synchronisation of timing by mobile units to synchronisation words transmitted from a base station.

Reference can be made to, for example, Mobile Radio Communications by Ray Steele, Pentech Press, 1992 for basic principles of tolerance to interferers in time division multiplexing.

The TETRA standard for trunked radio has provision for direct-mode communication, that is to say mobile-to-mobile communication without the need for any base station. The absence of any base station for frequency and timing reference gives rise to problems in adjacent channel and co-channel interference. To increase the frequency tolerance of the mobile

oscillator would increase its cost. Indeed there is a need to reduce the frequency accuracy of mobile equipment to reduce its cost.

Existing schemes for reducing interference call for changing the frequency of transmission to avoid the interferer, which is expensive in terms of channel usage, or increasing the channel spacing relative to the information transmission rate to combat inaccuracies in frequency references, which only makes the problem worse in the adjacent channel. Another way of reducing the effect of adjacent channel interference is to reduce the data rate for a given channel bandwidth, which is undesirable for reasons of throughput, and for reasons of complexity.

UK Patent Application No. 9400879.4 of Motorola Ltd. describes, among other features, a technique which reduces the effect of interference by randomly changing the frequency and time of the burst transmission, thus averaging the effect of the interferers over time. Time and frequency hopping is effective when there are a large number of available channels (and hence interferers), due to the interference averaging. Where there are smaller numbers of interferers, it does not necessarily reduce total or average interference.

There is a need to reduce interference in a TDMA communications system.

In direct mode TETRA, there is a single simplex communication link per carrier transmitting during one quarter of the available time in transmission bursts at a fixed (full rating) power during periodic time "slots". Because of the absence of a base station for timing synchronisation, units in a two-way communication or a group adopt an *ad hoc* time synchronisation, receiving from a transmitting unit, synchronising to that unit, and continuing the same slot sequence. The remaining three quarters of the time on the channel remains unused, with the exception that a dual watch feature is provided whereby a unit monitors the 18th frame of a TETRA control channel (which is transmitted approximately once every second) from a possible trunking base station to monitor for any incoming signalling (ceasing any direct mode transmission or reception to do so). Such an arrangement is inflexible with regard to interference management either generally or in emergency situations.

Summary of the Invention

According to a first aspect of the invention, a method is provided in a communications system having units communicating in periodic bursts over

a time divided channel where the interval between adjacent bursts from a given unit exceeds the duration of a burst. The method comprises the steps of: monitoring activity on a channel; identifying a periodic time window, repeating between peaks of activity on the channel, having a duration at least equal to the duration of a transmission burst; selecting that time window as a repeating time slot for transmission and transmitting during that repeating time slot.

As a matter of preference, the time window extending over a period of minimum activity on the channel is identified as the periodic time window.

A repeating frame structure may be applied to activity monitored on a channel such that regularly repeating peaks of activity are considered to fall in successive frames. Levels of activity may be averaged over a number of frames at different times in a frame so as to identify a periodic time window of low activity in a frame.

The inventors have identified that, in addition to the normal sources of interference, the link is subject to interference which is periodic at the same or integer divisions of the burst rate used on the link (i.e. TDM to TDM interference where the transmitter is the master timing reference). The invention provides a systematic way of reducing the effect of interference on the quality of the link.

The transceivers involved in the communication preferably have the capability to move the time at which they transmit and receive. The arrangement primarily applies when the timing reference is established by the transmitter independently of a master reference (i.e. the communication is essentially devoid of infrastructure). The time reference required for time burst transmission is set up between the two communicators. However, the arrangement may still apply within the constraints of a system, if the system allows the time of transmission to be altered, either independently of the system or by request to it.

The invention is particularly advantageous when there are a small number of interferers.

The activity on the channel may arise from co-channel activity or adjacent cannel activity spilling over into the channel in question. The first unit may or may not care whether the monitored activity is co-channel or adjacent channel activity.

In the case of a TETRA system, the invention has the advantage of reducing adjacent channel interference, because adjacent channel activity from another TETRA unit spilling over into the desired channel will occur with the same periodicity on the desired channel as the intended

transmissions from the first unit. The invention allows for selection of periods of minimum adjacent channel interference.

In accordance with this aspect of the invention, a communications device is provided comprising: a receiver for receiving signal bursts from a communications channel, the receiver having a channel monitor output for monitoring activity on the channel; a transmitter for transmitting in bursts of a predetermined duration on the channel and a computation device for analysing signals from the channel monitor output, for identifying repeating peaks of activity on the channel and for identifying a periodic time window, repeating between peaks of activity on the channel, having a duration at least equal to the predetermined duration. The transmitter is responsive to the computation device for selectively transmitting bursts during the identified periodic time window.

According to a second aspect of the invention, a method is provided of operation of a first unit for communication with a second unit over a time divided communications channel. The method comprises the steps of: receiving bursts of transmission from the second unit including traffic (and outputting the traffic at an output) and transmitting signalling to the second unit in bursts interspersed between received bursts on the same channel, where the first unit times the bursts transmitted according to the bursts received.

This arrangement provides for much greater flexibility in the communication link established.

The step of transmitting may comprise transmitting timing signalling to instruct the first unit to advance or retard the timing of its transmission bursts.

Activity may be monitored on the channel, the presence of an interfering source giving rise to periodic interference having the same period as the bursts from the second unit may be identified and a period of overlap at the first unit between a burst from the second unit and the interference from the interfering source may also be identified. A signal may be transmitted from the first unit to the second unit to adjust transmission timing to reduce the period of overlap.

In the case where the monitored activity is on-channel activity, the invention can allow for increased channel usage, or it can allow for minimum interference during pre-emption by a priority unit.

Pre-emption is a requirement of the TETRA specification. A direct mode unit initiating an emergency call out of coverage of the system must use a direct mode channel and, if necessary, pre-empt any communication

using that channel. There must be provision for a direct mode communication to be pre-empted in order to support the emergency calling service.

As an optional feature, activity on the channel is monitored at the first unit, the presence of a priority unit is identified and the step of transmitting comprises transmitting to the second unit a signal to cease transmission on the channel.

In this manner, pre-emption at a first unit by an emergency unit can be relayed to a second unit which may be transmitting to the first unit but is out of range of the second unit and is therefore not itself pre-empted.

The step of transmitting may comprise transmitting power control signalling to instruct the first unit to adjust the power of its transmission bursts.

The step of transmitting preferably comprises transmitting between fewer than one in two intervals between received bursts. For example, a single return burst may be transmitted every mulitframe (in the case of TETRA, this is once every 18 received frames or bursts).

In accordance with this aspect of the invention, a communications device is also provided comprising: a receiver for receiving signal bursts from a communications channel and extracting traffic information therefrom; a timer circuit for synchronising to received signal bursts and for providing transmit timing control signals; and a transmitter responsive to the transmit timing control signals to transmit signalling in bursts interspersed between received signal bursts.

Both the above aspects of the invention are combined in a method of communication between a first unit and a second unit over a time divided communications channel, comprising the steps of: transmitting in periodic bursts from the second unit to the first unit, and at the first unit, monitoring activity on the channel, identifying the presence of an interfering source giving rise to periodic interference having the same period as the bursts from the second unit and identifying a period of overlap at the first unit between a burst from the second unit and the interference from the interfering source, transmitting from the first unit to the second unit a signal to adjust transmission timing to reduce the period of overlap, and adjusting transmission timing at the second unit in response to the signal from the first unit.

In a further aspect of the invention, a method of communication between a first unit and a second unit over a communications channel is provided, comprising the steps of: transmitting from the second unit to the

first unit; monitoring activity on the channel at the first unit and identifying the presence of a priority unit; transmitting from the first unit to the second unit a signal to stop transmitting, and stopping transmitting at the second unit in response to the signal from the first unit.

This aspect of the invention has the advantage of relaying a pre-emption requirement from a receiving unit which may be in range of a pre-empting unit to a transmitting unit which may not be in range of the pre-empting unit. This aspect of the invention is independent of the nature of the channel or the multiplexing of the channel. The "channel" could be one of a number of types of communications resource.

Other aspects of the invention are defined in the claims.

A preferred embodiment of the invention is now described, by way of example, with reference to the drawings.

Brief Description of the Drawings

Fig. 1 shows a generic scenario of two users in a TDM communication with an interfering source.

Fig. 2 shows the periodic structure of bursts between units in Fig. 1 and the periodic nature of the interference in Fig. 2.

Fig. 3 shows the hardware elements of one of the units of Fig. 1.

Fig. 4 is a timing diagram illustrating operation of the unit of Fig. 3 in accordance with the preferred embodiment of the invention.

Fig. 5 is a flow diagram showing an algorithm for control of the unit of Fig. 3.

Fig. 6 is a timing diagram for illustrating certain aspects of the invention relating to pre-emption and

Fig. 7 is a timing diagram for illustrating certain aspects of the invention relating to signalling.

Detailed Description of the Preferred Embodiment

Considering the transmission system shown in FIG. 1 two transceivers 10 and 11 (which will be referred to as unit A and unit B) are TETRA radio transceivers capable of operating in direct mode. The transceivers could, of course be other types of transceiver.

Units A and B have been allocated a transmission channel for communication. This channel is, for example, a radio channel at a given frequency and with a given bandwidth. A and B do not necessary occupy

the channel all the time. When A and B are in communication, information is transmitted at regular times as bursts of fixed duration. The transmission channel is subject to interference from a source C.

FIG. 2 shows an example where information is transmitted for a fraction of the available time on the channel. In the example, this fraction is one quarter of the available time (the fraction should be at most one half for the present purposes). In the example, the dead time, during which no transmission is made, is unused and not allocated to any other user, as is the case in a TETRA system. The timing structure (i.e. the slot timing) may be established by A and B when the transaction is initiated.

The interference from source C is at the same repetition rate as the channel between A and B (or some integer divisor of that rate). The time phasing of the interference is asynchronous to that of the channel between A and B, and may occur at the same time that A and B are communicating (as shown in FIG. 2). In the example of a radio system, the interference may be co-channel or may be splatter from an adjacent channel. The adjacent channel splatter may arise because A and B and the interferer are operating independently from a stable frequency reference and their own references are not accurate enough to prevent power spilling out of their allotted bands.

The interference can now severely degrade the quality of the link between A and B. In the example, where the interferer is very close to A (but is transmitting in an adjacent channel), the effect of splatter into A and B's channel may completely obscure the communication.

A second related scenario can exist. In FIG. 1, C may not be an interferer, but may be a TETRA unit 12 wishing to signal to unit A and/or B. For example, C may wish to pre-empt the conversation between A and B and use the channel for a higher priority transmission. In this case, there is a risk that C may transmit while A and B are in communication, and the pre-emption signal may be lost due to interference from A and B.

To mitigate these problems, adaptive adjustment of burst transmission time is used.

By way of explanation, a diagram of the necessary hardware element of a unit 10 is given in FIG.3. The diagram applies to units 10, 11 and 12.

The unit 10 comprises a receiver 21, and a transmitter 22 which are both connected to an antenna 23 (if necessary via a duplexer) the receiver 21 provides traffic output to a loudspeaker 24, or other output (e.g. data fax etc.). In the case of voice, the output traffic generally requires decoding in a vocoder (not shown). A microphone or other input 25 is connected to

transmitter 22 for providing input traffic for transmission (again via a vocoder if necessary).

Connected to the transmitter 22 and receiver 21 is a synthesizer 30 for frequency control. A microprocessor 31 is provided for overall control of the unit. The microprocessor has timing circuitry 32 and has a memory 33. A push-to-talk (PTT) button or other input 34 is connected to the microprocessor 31. Connected between the microprocessor 31 and the transmitter 22 are shown a signalling data line or bus 40 and a control line 41. Connected from the receiver 21 to the microprocessor 31 are shown a received signal strength indicator (RSSI) line 42 and a receive signalling line or bus 43. A frequency control bus 44 is connected between the microprocessor 31 and the synthesizer 30.

Considering first the case where the unit wishes to transmit on a vacant channel. The microprocessor 31 selects an appropriate frequency via frequency control bus 44 and the receiver 21 receives signals from the channel and gives an indication on RSSI line 42 as to the activity on the channel. Assuming the case where the channel is empty, the user can press the PTT button 34 and the microprocessor 31 controls the transmitter 22 via control line 41 to transmit traffic from the microphone 25 in time divided manner over one quarter of the channel. The timing, controlled by timer 32, is on a predetermined periodicity, i.e. fixed frame length, predetermined according to the system configuration. By virtue of transmitting bursts on the channel, the unit 10 has effectively defined time slots for transmission and windows of inactivity between those time slots.

When the unit 11 wishes to reply, it monitors on its RSSI line 42 the activity from unit 10 and synchronizes its frame timing to the received "slot". Unit 11 maintains the same timing and, when unit 10 has ceased transmission and unit 11 commences, it continues to transmit bursts in the same periodic sequence, i.e. the same "slots". To an external observer, there need not be substantial difference in the timing of the slot sequence between one unit transmiting and the other unit transmitting.

A significant new feature of one aspect of the invention is the provision of a return signalling channel from a unit that is receiving traffic to a unit that is transmitting traffic.

Considering the case where unit 10 is receiving, bursts of traffic are received in receiver 21 and output at loudspeaker 24 (or some other output). The RSSI signal 42 indicates the rising and falling of the incoming bursts to the microprocessor 31. The microprocessor 31 defines a return signalling transmission slot which falls between the end of one received burst and the

start of the next received burst. For example, the return transmission signalling slot has the same duration as a received traffic slot (i.e. one quarter of a frame) and is positioned centrally between the end of one received traffic slot and the beginning of the next anticipated received traffic slot. The microprocessor 31 causes the transmitter 22 to key up and transmits signalling information via signalling line or bus 40.

The transmit signalling slot need not occur in every frame. It may occur in alternate frames or indeed it may be quite infrequent. For example, it may occur every multiframe, equating to about one return signalling slot per second. In TETRA a multiframe comprises seventeen frames of traffic and one frame of signalling (in the same direction).

As will be described below, this return signalling slot can be used for timing control or for pre-emption control. Indeed, this return signalling slot can be used for power control also.

An algorithm is provided in the memory 33 of units A and B, which involves adjusting the time at which a transmission is made, to avoid interferences of the nature shown in FIG.2.

The algorithm involves three basic steps: (1) monitor the power received in the channel of interest and determine the period of minimum interference within the repetition rate of the transmission (2) when transmitting, adjust the time at which transmission occurs so that the transmission lies within the time of minimum interference and (3) signal to the other party in the transmission to align its timing with the first party.

The adjustment of transmission time is systematic, so that the interference is completely avoided. Systematic adjustment of transmission time is generally applicable to situations when the number of potential interferers is small.

In order to illustrate the algorithm, consider again the example given in FIG. 1. A and B are radios which have been allocated a channel for direct mobile-to-mobile communication. The example system under which the radios operate uses a 4:1 slotted time slotted structure shown in FIG. 2. C is a radio using a similar channel adjacent to A and B's. A, B and C are operating independently of any system infrastructure, and the inaccuracies in the frequency references within the radios are large enough to cause significant adjacent channel interference.

Various cases are considered with reference to FIG. 4, in which signal Q is measured activity (interference) on a channel in question, signal R is transmission with timing adjusted to quiet spots on the channel and signal S is transmission adjusted to maximise throughput on the channel.

A first case will be considered addressing interference detected prior to call set-up.

When idle, A and B monitor their own channel for periodic interference. If C is transmitting, signal Q shows the signal power measured by A and/or B in their own band. The periods of increased measured power are due to C splattering into A and B's band. If A now wishes to transmit to B, A chooses to transmit in the periods of least interference in between C's transmissions (signal R). B will detect A's signal and will adjust its timing to transmit during the same time slots. No additional signalling is required to adjust B's initial timing.

The novel signalling scheme described above with reference to FIG. 3 is used for a receiving unit to provide control signalling back to a transmitting unit. If the relative timing between the interferer and A and B's transmission drifts, then A or B will send signalling messages at periodic intervals to adjust their timing, thus tracking the optimum time to transmit (or quiet spot).

If the radio which initiates the call is out of range of the interferer, so that the called radio is the one that is interfered with, the called radio can signal the initiating radio to adjust its timing away from the interferer.

Alternatively, signal S of FIG. 4 shows a scheme where A and B adjust their timing to occupy a "slot" next to that containing the interference. This ensures that the unused time in the frame structure (i.e. without A or B transmitting and without interference), which in this case is two slots, is contiguous. This large window can be used for pre-emption or signalling from an associated infrastructure, or even for another conversation.

A second case will be considered where interference is detected after call set-up.

If A and B are already communicating when interference occurs, then the return signalling channel, used (as described above) to track the quiet spot, is used to move to a slot away from the interferer. It is interesting to note that if this technique is adopted across a radio system, then this scenario will only happen at the edge of the bands. If C is part of the same system as A and B, it will avoid A and B's time slot if it sets up its call after A and B.

A third scenario is the case where a third party wishes to break into a transmission (as in the case of pre-emption). The third party can synchronize to the transmission prior to sending a pre-emption message. This is subtly different from avoiding interference, in that direct time and

frequency synchronisation takes place prior to transmission. In avoiding interference, A or B looks for the period of least interference. A or B does not actively synchronize to another transmission.

An example of the algorithm stored in memory 33 for controlling the microprocessor 31 is shown in Fig. 5. Upon inputting of a PTT signal (step 100) at PTT input 34, the microprocessor 31 determines in step 101 whether there is activity of a periodic nature on the channel. This is done by monitoring of RSSI signal 42. The microprocessor 31 applies a frame structure to the RSSI signal, effectively dividing it into frames (of predetermined duration according to the system) and assumes that peak activity occurring at a regular point in the frame is activity from another unit on the system. It measures the signal level at different points in the frame (samples) and averages these samples over several frames. If there is no such periodic activity, the unit can simply seize the channel (step 102). If there is periodic activity, step 103 considers the case of an emergency transmission. If the transmission is a priority transmission, a window of least activity is identified in step 104 and, during this window, a signal is transmitted effectively indicating to other units to get off the channel. Because the signal is transmitted at the period of least activity on the channel, it has the greatest likelihood of being received at other units.

Note that all units have a new feature of monitoring for such signalling either throughout the quiet period on the channel, or at the midpoint between traffic bursts on the channel. After several frames of transmitting this signal in step 105, the priority unit simply accesses the window of least activity as a "time-slot" and commences transmitting in that time-slot. It is the responsibility of other units to cease their transmission upon receipt of the pre-emption signal.

Where the transmission is not a priority transmission, step 110 identifies the window of least activity (identical to step 104). The noise floor during this window is measured and if, in step 111, the noise floor falls below a predetermined threshold, it is determined that the noise floor is low enough to allow transmission and the identified "time-slot", i.e. the window of least activity is used for transmission in step 108. If in step 111 the noise floor is to high for transmission, the unit can try a different channel in step 112 (assuming that it has more than one channel capability).

It may be noted that step 111 allows the unit to access the channel based solely upon the minimum noise level on the channel. This noise level many be low even in the event of existing on-channel activity (e.g. an on-channel user at some distance). This feature allows for greater channel

usage. Other criteria may be set. For example, if the level of peak activity is too high, it can be arranged to that the unit avoids the channel altogether. This may be necessary to allow existing users on the channel exclusive use of the quiet time, for example, for signalling.

If A and B are already communicating, and C wishes to pre-empt the call, it will synchronize to the transmission of A and B, and will send its pre-emption message in the slot mid-way between the two. In order for pre-emption to be accomplished, A and B listen to the slot midway between their own slots, either every frame or every N^{th} frame. Hence, the radio must be able to switch between transmit and receive within one slot in a four slot system. This is illustrated in FIG. 6.

Fig. 6 shows, at the top, a frame structure established by units A and B and beneath the frame structure it illustrates transmitted "slots". In the lower part of the figure are shown "slots" which represent opportunities for C to pre-empt the ongoing conversation between A and B, after synchronizing to A/B's frame structure. As shown, the pre-emption signal from C is placed midway between transmitted slots from A or B, thereby giving units A and B the maximum possible time to switch from transmit to receive in order to receive the pre-emption signal.

There are a number of important benefits of adaptive adjustment of burst transmission time. These are: reduced interference, leading to more reliable and better quality links; reduced frequency stability and adjacent channel specifications for communication equipment; and increased spectral efficiency and the possibility to share channels in time within an infrastructureless system. The first of these benefits is due to transmitting and receiving when the interference is absent. The second benefit is because adaptive burst transmission time isolates the receiver from interference in time rather than frequency. This is preferable (or additional) to placing very tight specifications on the allowable drift of transmitters (by specifying a highly accurate reference in the radios) and tight specifications on the splatter allowed from one band into another (which requires tightly specified filters and very linear transmitter amplifiers). By isolating in time, these specifications can be relaxed, making the radios less expensive.

One further benefit is that it provides the mechanism to adjust slot timing via the return signalling channel. This mechanism may also be useful for other functions of the radio. For example, FIG. 7 shows the transmissions between two radios that may be engaged in a conversation independent of an infrastructure that they both belong to (direct mode in a

trunked system). One radio may be in coverage of the system, the other not. It may be a requirement that a trunked system can interrupt the conversation between the radios. In order to implement interruption by the system, the radio in coverage must listen to the infrastructure on another channel. However, the timing of the slots in the system will be unrelated to the timing structure of the direct mode call. The infrastructure may call the radio within its coverage while it is listening to its direct mode conversation. In order to avoid clashing with the direct mode call, the radio in coverage can adjust the timing of the direct mode call so that it has a window of opportunity between direct mode slots to listen to the infrastructure at the right point in time. This is similar to pre-emption, but in this case, the call in progress adjusts its timing to align with the potential interrupter (the trunked system), rather than the interrupter synchronising its timing to that of the call in progress. The return signalling channel is important in achieving this realignment of slot timing.

Note that, in this case, the return signalling channel occupies each 12th slot on the established traffic slot sequence between units A and B (instead of the mid-point between these slots as described above). This is not essential, but is merely illustrated as an alternative arrangement.

As an alternative to having fixed burst durations and adjusting timing of start and end of transmissions, the burst duration can be adaptively changed to fill the quiet spots and maximise the transmission rate.

This invention is applicable to any situation when a call between two parties uses a slotted time structure to communicate and potential interference sources use the same repetition rate. An example is TETRA direct mode. The proposal for TETRA direct mode is to use a 4:1 slot structure with one slot used per carrier so that direct mode remains compatible with the TETRA trunked standard. However, when free of the trunked system, the inaccuracy the radios' frequency references causes significant adjacent channel interference. Also, direct mode in TETRA must support channel pre-emption (presently undefined) and the ability for the infrastructure to break into a call on a different channel (dual watch).

The technique described and claimed applies particularly to situations where there is a limited number of interferers, a low number of available channels and the communication is essentially infrastructureless. The method provides a systematic avoidance of interference in the time domain without the need of a system wide timing reference and allows an

improvement in spectral efficiency for infrastructureless systems without imposing stringent specification on the local frequency reference.

Claims

1. In a communications system having units communicating in periodic bursts over a time divided channel where the interval between adjacent bursts from a given unit exceeds the duration of a burst, a method comprising the steps of:

monitoring activity on a channel,

identifying a periodic time window, repeating between peaks of activity on the channel, having a duration at least equal to the duration of a transmission burst

selecting that time window as a repeating time slot for transmission and

transmitting during that repeating time slot.

2. A method according to claim 1, wherein a time window extending over a period of minimum activity on the channel is identified as the periodic time window.

3. A method according to claim 1, comprising the step of applying a repeating frame structure to activity monitored on a channel such that regularly repeating peaks of activity are considered to fall in successive frames and averaging over a number of frames levels of activity at different times in a frame so as to identify a periodic time window of low activity in a frame.

4. A communications device comprising:

a receiver for receiving signal bursts from a communications channel, the receiver having a channel monitor output for monitoring activity on the channel;

a transmitter for transmitting in bursts of a predetermined duration on the channel and

a computation device for analysing signals from the channel monitor output, for identifying repeating peaks of activity on the channel and for identifying a periodic time window, repeating between peaks of activity on the channel, having a duration at least equal to the predetermined duration;

wherein the transmitter is responsive to the computation device for selectively transmitting bursts during the identified periodic time window.

5. A method of operation of a first unit for communication with a second unit over a time divided communications channel, comprising the steps of:

receiving bursts of transmission from the second unit including traffic and

transmitting signalling to the second unit in bursts interspersed between received bursts on the same channel, where the first unit times the bursts transmitted according to the bursts received.

6. A method according to claim 5, wherein the step of transmitting comprises transmitting between fewer than one in two intervals between received bursts.

7. A method according to claim 6, wherein the step of transmitting comprises transmitting one burst for every multiframe of received bursts.

8. A method according to claim 5, 6, or 7, wherein the step of transmitting comprises transmitting timing signalling to instruct the first unit to advance or retard the timing of its transmission bursts.

9. A method according to any one of claims 5 to 8, comprising the step of, at the first unit, monitoring activity on the channel, identifying the presence of an interfering source giving rise to periodic interference having the same period as the bursts from the second unit and identifying a period of overlap at the first unit between a burst from the second unit and the interference from the interfering source, wherein the step of transmitting comprises transmitting to the second unit a signal to adjust transmission timing to reduce the period of overlap.

10. A method according to any one of claims 5 to 9, wherein the step of transmitting comprises transmitting power control signalling to instruct the first unit to adjust the power of its transmission bursts.

11. A method according to claim 5 comprising the step of, at the first unit, monitoring activity on the channel and identifying the presence of a priority unit, wherein the step of transmitting comprises transmitting to the second unit a signal to cease transmission on the channel.

12. A method of communication between a first unit and a second unit over a time divided communications channel, comprising the steps of:

transmitting in periodic bursts from the second unit to the first unit, and

at the first unit, monitoring activity on the channel, identifying the presence of an interfering source giving rise to periodic interference having the same period as the bursts from the second unit and identifying a period of overlap at the first unit between a burst from the second unit and the interference from the interfering source,

transmitting from the first unit to the second unit a signal to adjust transmission timing to reduce the period of overlap, and

adjusting transmission timing at the second unit in response to the signal from the first unit.

13. A communications device comprising:

a receiver for receiving signal bursts from a communications channel and extracting traffic information therefrom;

a timer circuit for synchronising to received signal bursts and for providing transmit timing control signals,

a transmitter responsive to the transmit timing control signals to transmit signalling in bursts interspersed between received signal bursts.

14. A method of communication between a first unit and a second unit over a communications channel, comprising the steps of:

transmitting from the first unit to the second unit,

at the second unit, monitoring activity on the channel and identifying the presence of a priority unit;

transmitting from the second unit to the first unit a signal to stop transmitting, and

stopping transmitting at the first unit in response to the signal from the second unit.

15. A pair of communications units adapted for communicating traffic between each other over a communications channel, a first unit of the pair having means for monitoring activity on the channel and identifying the presence of a priority unit and having a transmitter for transmitting to the other unit of the pair a signal to stop transmitting and the other unit having means for stopping transmitting at the first unit in response to the signal from the first unit.

16. A communications device adapted for communicating traffic over a communications channel, the device comprising:

monitoring means for monitoring activity on the channel and identifying the presence of a priority unit;

a transmitter for transmitting over the channel a signal to command another units to stop transmitting in response to identifying the presence of a priority unit on the channel;

control means for stopping further transmitting in response to the identification of the presence of a priority unit and

a receiver for receiving from the channel a command signal to stop transmitting, wherein the control means are additionally arranged to stop transmitting in response to the command signal.

Patents Act 1977 19 Examiner's report to the Comptroller under Section 17 (The Search report)	Application number GB 9415435.8
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Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASES: WPI, INSPEC	Documents considered relevant following a search in respect of Claims :- 1-13

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Category	Identity of document and relevant passages	Relevant to claim(s)
X	EP 0149136 A1 (IBM) whole document	1,4,5,12 and 13

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